LASER SOURCES FOR STANDOFF CHEM-BIO DETECTION

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ABSTRACT

The US Army Edgewood Chemical Biological Center is the leader in development of military laser-based systems for chemical and biological defense, in collaboration with all Services, other Government laboratories, academia, and industry. Chemical and biological (CB) laser sensing principles, unique capabilities, state-of-the-art sensors, and emerging technologies will be discussed. Expected advancements in laser sources for CB detection offer significant improvements to the operational capability of the Future Combat System (FCS) and Future Force Warrior (FFW) in the area of Force Protection against the CB threat.

1. CHEMICAL STANDOFF

The Artemis Chemical Standoff program performed an Analysis of Alternatives that was completed in July 2001. Because of the increased importance of aerosol detection, the conclusion of the AoA was that the alternative with greatest effectiveness in terms of military worth is multiple-wavelength, long-wave infrared (LWIR) Light Detection and Ranging (LIDAR) technology. Specifically, Artemis Increment I technology is based on a carbon dioxide (CO2) Frequency Agile LIDAR (FAL) developed at ECBC by Raytheon, El Segundo, CA with expertise from the US Army Night Vision and Electronic Sensors Directorate (NVESD).

The Artemis program is currently in a Component Advanced Development (CAD) phase. Three focus areas were identified for CAD efforts: 1) extension of optics lifetimes, 2) combined vapor and aerosol algorithms (ongoing), and 3) wavelength conversion to 8.3 microns for enhanced mustard detection. The first effort is complete, with an improvement of optics lifetimes from 8 million to 100 million shots with the use of a particulate precipitator.

The third effort has demonstrated record efficiency in going from 10.6 to 8.3 microns in a 2-stage conversion process – second harmonic generation (SHG) then Optical Parametric Oscillation (OPO) – at low repetition rates. At high repetition rates, thermal lensing was observed in the SHG/OPO bars, as expected. To mitigate this effect, the plan is to replace large, single bar crystals with multiple, cooled slab crystals.

In addition to the CO2 laser, tunable 8-12 micron solid-state laser sources and conversion crystal damage mitigation are under development for Future Force applications. Mid-wave IR (MWIR) lasers (3-5 microns) hold much promise for detection of Toxic Industrial Chemicals (TICs). Also, a study of heterodyne detection with regard to real-world averaging statistics is ongoing.

2. BIOLOGICAL STANDOFF

Conventional standoff biodetection methods are near-IR (NIR) elastic scattering and ultraviolet (UV) laser-induced fluorescence (LIF). The former provides long ranges but no discrimination of clouds beyond man-made vs natural. The latter provides discrimination of clouds to at least bio vs non-bio, but at the cost of range. Three scattering systems known as the XM-94 were deployed, and 2 improved prototypes were produced before cancellation of the program. One LIF prototype saw extensive testing, and 2 downsized prototypes have been developed.

In the technology base, several non-conventional Bio-Discrimination approaches are under analysis. A user-weighted technology downselection, with heavy emphasis on maturity, was conducted in 2002. As a result, LWIR and MWIR, active (Differential Scattering, DISC) and passive spectroscopy is under evaluation to determine sensitivity of the technologies. Existing demonstrator systems such as the FAL are being characterized.

In order to acquire highly quantified data, study the effects of variables such as particle size distribution on backscatter coefficients, perform iterative aerosol algorithm development, and characterize breadboards, a novel “windowless” Vortex chamber was developed and built at ECBC. The chamber utilizes curtains of air to contain the cloud, thus preventing the inevitable backscatter off of conventional windows from corrupting the desired measurements. This feature is critical because the CO2 lidar has a long (1 microsecond) pulse and the backscatter off the window cannot be temporally separated from the backscatter off the aerosol in the

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chamber. The chamber was designed for testing with a variety of CB simulants and interferents in both vapor and aerosol form and has been successfully shown to contain a cloud of known size, concentration, and particle size distribution for 10-15 minutes. The measurements clearly show the effect of size distribution on the infrared backscatter coefficients as well as the dynamic nature of the size distribution for a population of aerosols.

The well-known chemical detection techniques of Differential Absorption LIDAR (DIAL) and Differential Scattering (DISC) have been under theoretical and field test investigation for at least 20 years and are now at a high level of sophistication. With development of a more energetic lidar, extension of these techniques to biological detection can be considered. Absorption cross-sections of biological aerosols are at least 2 orders of magnitude less than those of chemical vapors, hence DIAL and RR-DIAL techniques (which rely on absorption) do not appear to be viable for detection of expected threat levels of biological agents. Scattering cross-sections for bio aerosols, however, are sufficiently greater than those for natural aerosols so as to allow DISC to be a viable technique for meaningful biological agent detection. The obvious advantage here is that one standoff detector could be used to detect both a chemical and a biological agent threat.

3. INTEGRATED & SURFACE DETECTION

Two new initiatives are under analysis at ECBC: integrated chem-bio detection and surface detection. Feasibility studies will be performed to integrate chemical and biological detection capabilities into a single sensor, while maintaining the same performance objectives. Examples of how CO2 and solid-state lasers can become integrated detectors will be shown. An inherent advantage of solid-state lasers is that peak powers are greater in their shorter pulses as compared to long CO2 pulses, therefore, less pulse energy is required. However, waveguide CO2 lasers offer significant advantages as well. Reducing the size of either type of laser will allow battery-powered standoff techniques to be employed on smaller platforms, such as FCS and UAV, and for FFW applications.

Surface detection presents significant challenges. Four technologies are currently under analysis: UV Raman scattering, thermal luminescence, thermal IR, and Laser Induced Breakdown Spectroscopy (LIBS).

CONCLUSION

Near-term plans are focused on characterization of laser demonstrators for standoff bio discrimination and deducing absolute backscatter coefficients from the Vortex Chamber data.